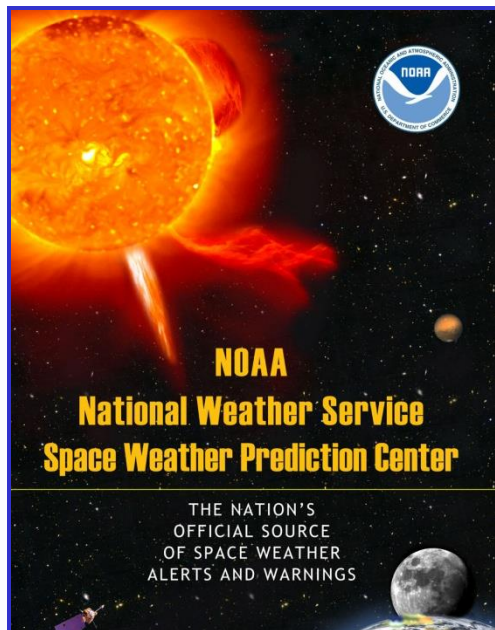




# The Evaluation of Geospace Models for Transition to Operations



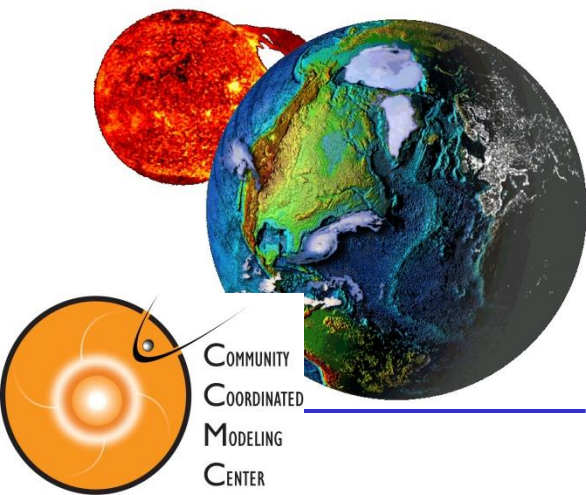
## Outline:

- Customer Needs (selected examples)
- Geospace Model Project and Partners
- Selection Process
- Conclusions

Acknowledgments: Balch, NASA CCMC (Kuzentsova, Pulkkinen, Rastaetter), Geospace Modelers

Howard J Singer- NOAA Space Weather Prediction Center  
Antti Pulkkinen – Community Coordinated Modeling Center  
Terry Onsager – NOAA space Weather Prediction Center

Space Weather Workshop, Boulder CO, April 28, 2011



*Safeguarding Our Nation's Advanced Technologies*



# Electrical Power Grid...



- **The grid is becoming increasingly vulnerable to space weather events**

*Future Directions in Satellite-derived Weather and Climate Information for the Electric Energy Industry – Workshop Report Jun 2004*

• **“...blackouts could exceed even that of the very large blackout that occurred in August 14, 2003. And there is no part of the U.S. power grid that is immune to this... we could impact over 100 million population in the worst case scenario.”**

John Kappenman - before U.S. House Subcommittee on Environment, Technology & Standards Subcommittee Hearing on “What is Space Weather and Who Should Forecast It?”



From the  
NRC report:  
The  
Economic  
And Societal  
Impacts of  
Space  
Weather

# High-level government response...

Coordinating on ways forward to develop and implement mitigation strategies to safeguard critical infrastructure from the impacts of severe space weather.

- **The Shield Act (H.R. 668) (Feb 2011)**  
To amend the Federal Power Act to protect the electric infrastructure geomagnetic storm (and EMP)
- **Meeting at White House with National Security Staff and OSTP (18 Feb)**
- **Op Ed in NY Times on space weather by Holdren and Beddington (10 Mar)**
- **Electric Infrastructure Security Summit (EISS) in Washington D.C. (11 Apr)**







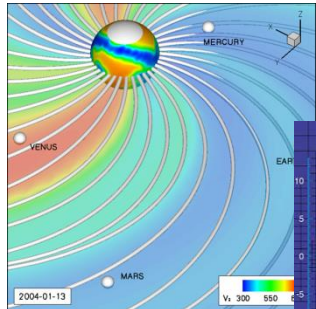
# Model Transition to Operations



• *Partnering with NASA's Community Coordinated Modeling Center, DOD, and the research community to develop improved space weather models to maximize the utility of solar wind and CME data for extended forecast and warnings*

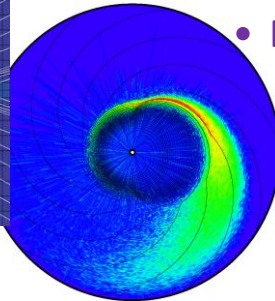
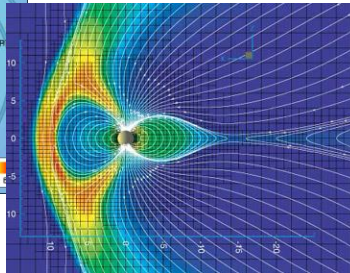
- **Solar Wind Disturbance Propagation Model**

- Geomagnetic storm predictions go from ~1 hour to 18hr to 4 days



- **Geospace Response Model**

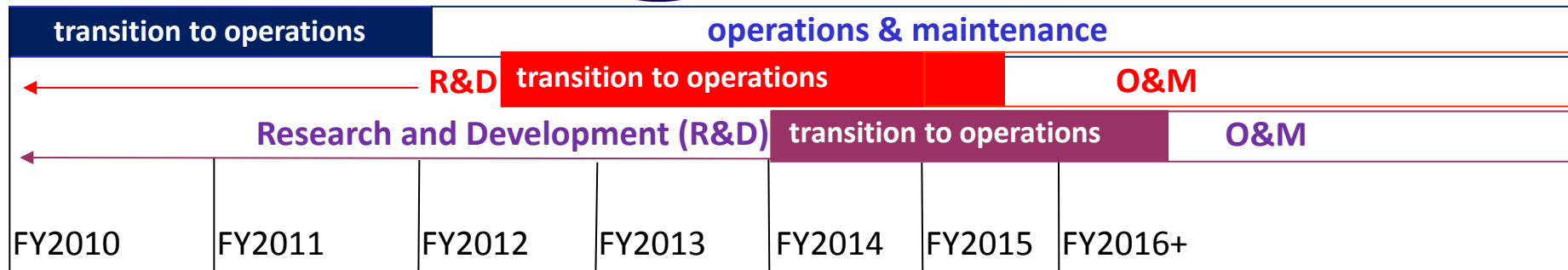
- Will replace limited value global predictions with actionable regional forecasts and warnings



- **Energetic Particle Transport Model**

- Model to predict radiation storm peak intensity, timing, and spectrum; no models currently exist!

- **Ionospheric Forecast Model**



O&M includes Operation to Research (O2R) feedback to continuing R&D



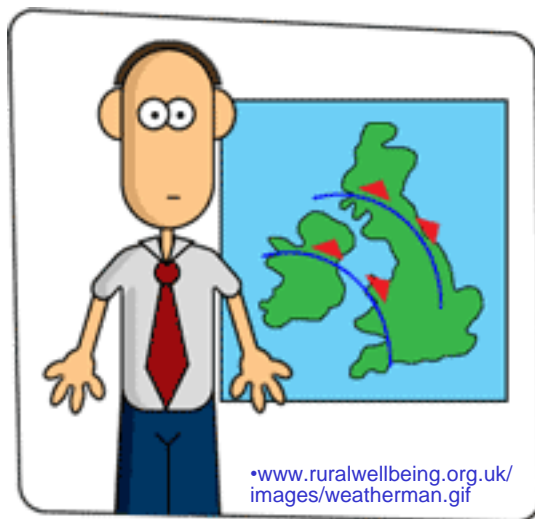
# Geospace Model Project Goals

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- **Goal:** Evaluation of Geospace prediction models to determine which model or models should begin transition to operations process beginning January 2012.
- **Focus:** Models that can predict regional geomagnetic activity
- **Process:** CCMC leads evaluation; Build on GEM Storm Challenge; Establish partnerships; Select metrics; Conduct evaluation
- **Community Discussions:** GEM, AGU, and CCMC Meetings; Geomagnetic activity products documents circulated, Geospace Model Validation Workshops...

# Today's Forecast



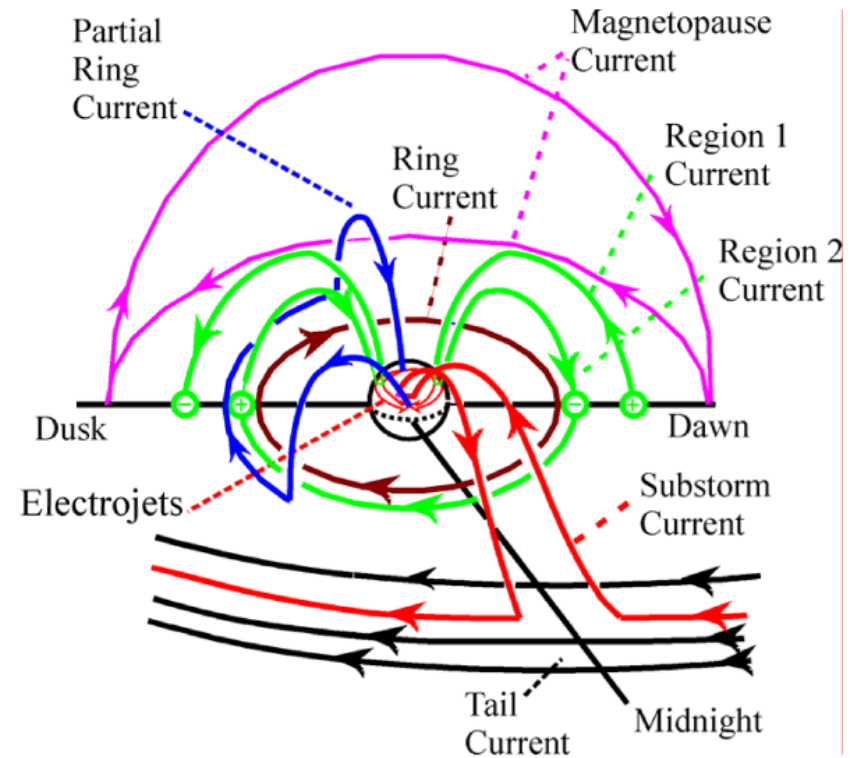
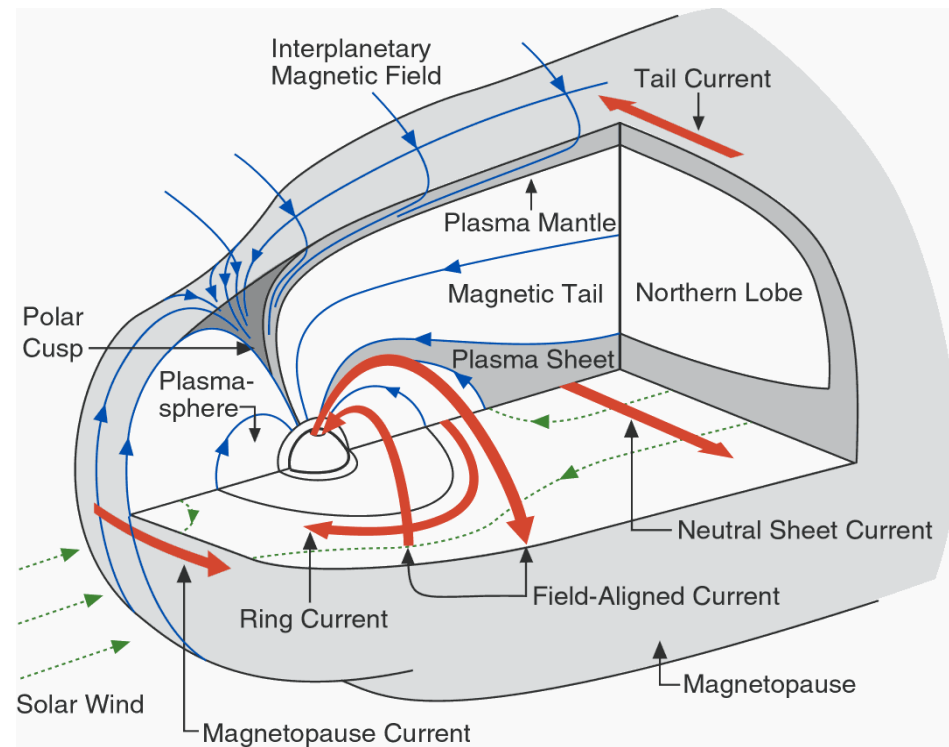
“The forecast is for rain, somewhere on Earth, sometime today.”



Is this an analogy to geomagnetic disturbance products today?

Perhaps a slight exaggeration, nevertheless there is a need for regional forecasts with longer lead time.

# SOLAR WIND – INDUCED ELECTRIC CURRENTS FLOWING IN THE MAGNETOSPHERE



Credit: Kivelson and Russell, Introduction to Space Physics



# Models at CCMC Participating in Geospace Evaluation



- **MHD Models:**
  - Space Weather Modeling Framework (SWMF) - U. of Michigan (delivered to CCMC)
  - The Open Geospace General Circulation Model (Open GGCM) - University of New Hampshire (delivered to CCMC)
  - Coupled Magnetosphere-Ionosphere-Thermosphere (CMIT) - BU CISM, Dartmouth, NCAR (delivered to CCMC)
  - Grand Unified Magnetosphere-Ionosphere Coupling Simulation (GUMICS) - Finnish Meteorological Institute  
(not yet parallelized or ready for full evaluation, but showing progress)
- **Empirical Models**
  - Weimer Empirical Model, Va. Tech (delivered to CCMC/may update)
  - Weigel Empirical Model, George Mason (delivered to CCMC)





# CCMC Capabilities with regard to the Geospace Model Evaluation

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- CCMC has extensive experience in hosting and running large-scale space plasma models developed by the international space physics community. Day-to-day communication and collaboration with the model developers.
- CCMC has extensive experience in running many of the hosted models in real-time mode and generating tailored space weather products. Products are disseminated via the innovative iSWA ([iswa.gsfc.nasa.gov](http://iswa.gsfc.nasa.gov)) system.
- CCMC has extensive experience in systematic validation of large-scale space plasma models. Recently CCMC has been supporting GEM, CEDAR and SHINE modeling challenge activities.



# CCMC Capabilities with regard to the Geospace Model Evaluation



- All the participating models were delivered by the deadline and CCMC has successfully installed and tested all global MHD models (using Halloween storm event). Extensive communication with the model developers ensures correct installation and appropriate settings of the models.
- CCMC is working on extracting the ground magnetic field perturbations from global MHD models (integration over magnetospheric and ionospheric current systems).
- Per discussions with SWPC and model developers CCMC has carried out initial tests to assist the selection of the final evaluation metrics. Evaluation metrics calculations will be carried out by CCMC.



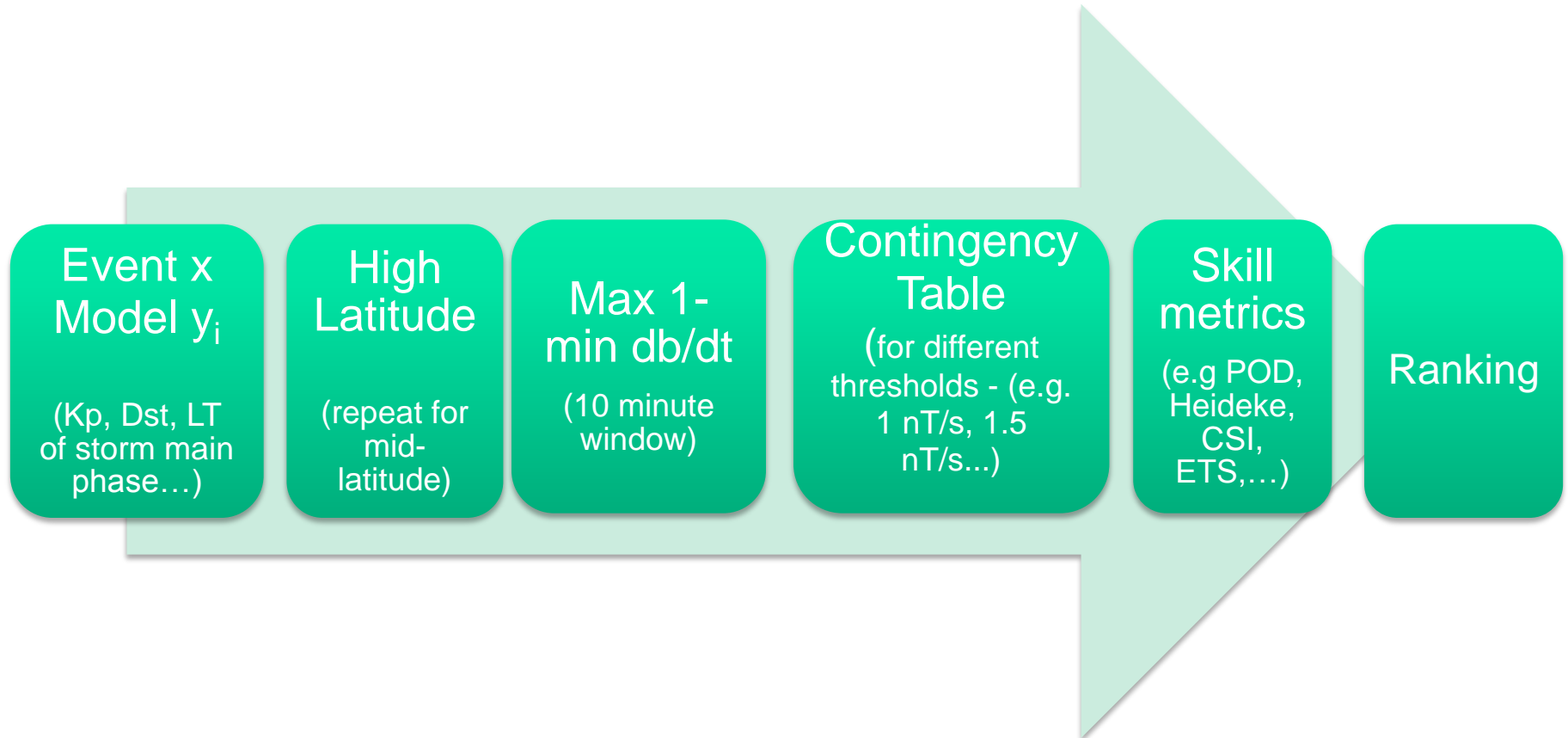
# Regional dB/dt Prediction

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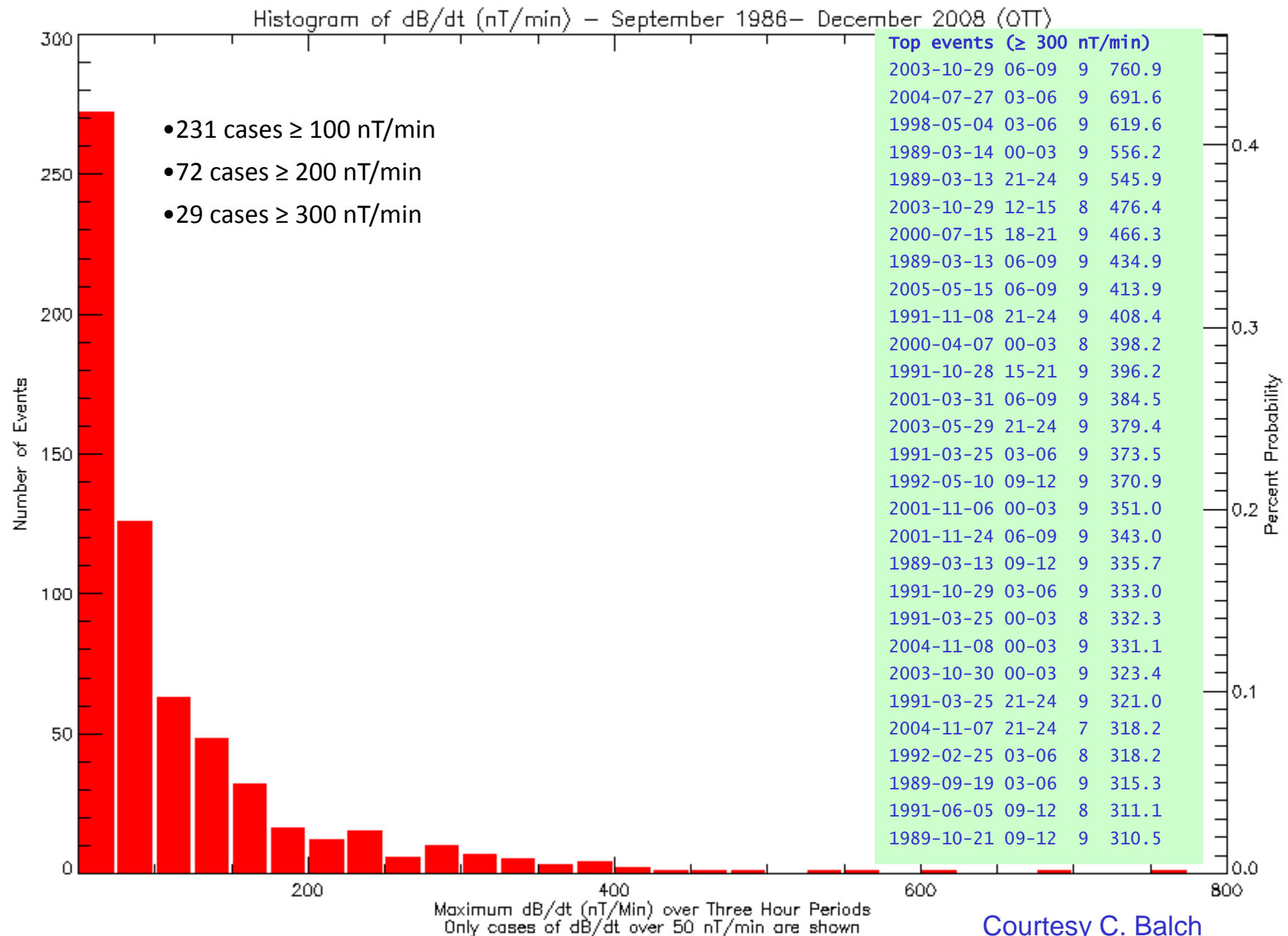
## Challenge

- How well can MHD models predict a regional (TBD) dB/dt (e.g. max disturbance, average disturbance, log-spectral distance) compared to the ground observed value over specified time interval (TBD)
- Currently Available: No product

# dB/dt Evaluation

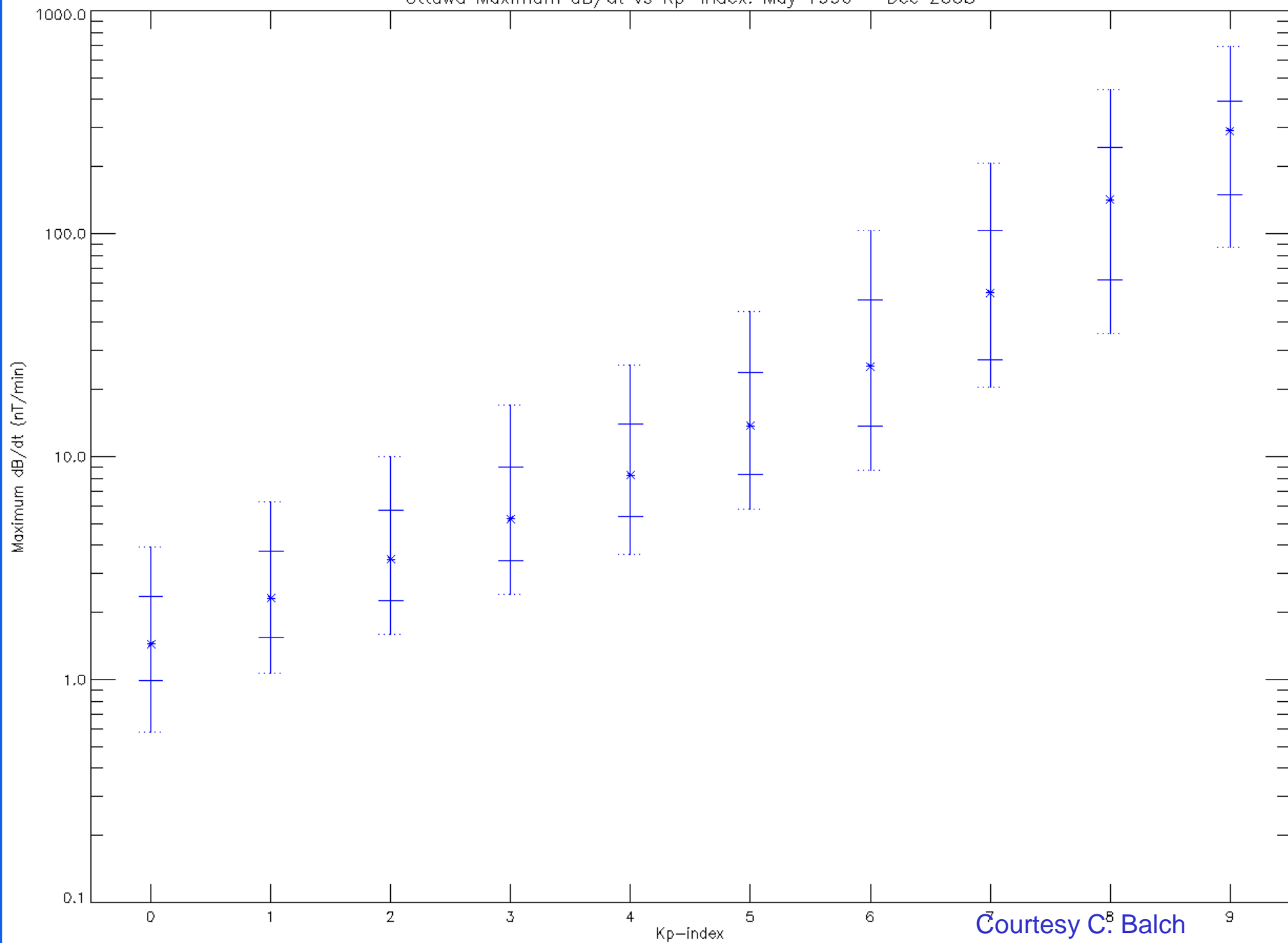






Courtesy C. Balch

Ottawa Maximum dB/dt vs Kp-index: May 1996 - Dec 2008





# Regional K Prediction

## Challenge

- Can MHD models predict a regional (TBD) K that better represents a local geomagnetic disturbance than the currently available global Kp over specified time interval (TBD)?
- Currently Available: Wing Kp predicted from solar wind input at 15-min cadence and AF 3-hour near-real time Kp observed index



# Geospace Model Recommendation Process

- Models will be evaluated on four criteria:
  - Strategic Importance
  - Operational Significance
  - Implementation Readiness
  - Cost to Operate, Maintain, and Improve
- Evaluation team will consist of internal and external participants
- Modelers to review and comment on draft Recommendation Report prior to delivery to SWPC Director
- The final Recommendation Document will be made public
- Selection will be made by SWPC Director



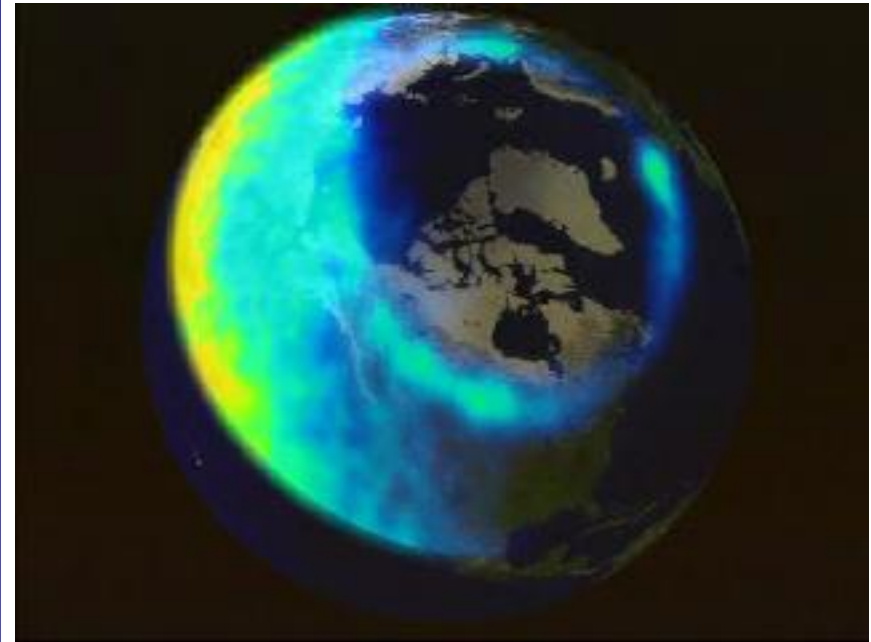


# Possible Findings/Recommendations

- One (and only one) MHD model has sufficient value to justify transition and operation costs – Recommend transition
- Multiple MHD models have sufficient value – Recommend one model based on highest long-term value and lowest cost
- No MHD model has sufficient value, but near-term improvements could be made – Recommend SWPC support for additional development and testing
- One or both empirical models have sufficient value – Recommend either or both for transition
- No model has sufficient value – Recommend no SWPC action

# Secondary Geomagnetic Activity Products and Metrics

- MHD Model Auroral Products
  - Latitude, width, local time, and intensity of the auroral electrojets
  - Related to locations of large  $dB/dt$ 's
  - Related to location of HF radio absorption
  - Provides location of polar cap where Solar Energetic Particle's have access and can disrupt HF radio communication
  - Energetic particle precipitation
  - Metrics need to be developed
  - Potential data sources for comparison include: AMPERE, DMSP, POES, ground-based magnetometers



Polar Visible Aurora:  
High Solar Wind Conditions on  
April 17, 1999 over the North Pole

- Geosynchronous orbit magnetopause crossing
- Ionosphere: products and disturbances; e.g TEC



# Conclusions

- **Space weather customers will benefit from improved regional geomagnetic activity predictions**
- **$dB/dt$  and regional K are a primary need**
- **Auroral and ionosphere products are an additional outcome**
- **Physics-based models have reached a level of maturity where it is expected they can provide valuable products for space weather customers**
- **Empirical models serve as a valuable baseline and possible independent product**
- **Establishing metrics for model evaluations is a challenge and we benefit from the GEM studies**
- **Operational supercomputing capabilities are available**
- **CCMC is key for an independent validation of models available for transition to operations**
- **SWPC values the continuing support and expertise provided by modelers and other partners**